NONLINEAR BAROTROPIC INSTABILITY IN THE STRATOSPHERE

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Abstract

A number of linear studies suggest that some planetary scale waves in the stratosphere may arise from barotropic instability; the behavior of these barotropic modes at finite amplitudes has not previously been explored. Several idealized profiles representative of stratospheric winds are used in a nonlinear barotropic model to examine the types of behavior that may occur when barotropically unstable waves grow to finite amplitudes. For each wind profile, nonlinear integrations are done for a number of wind speeds and Rayleigh friction parameters within a range of values that might be observed in the stratosphere,

For easterly or westerly wind profiles for which the vorticity gradient changes sign in midlatitudes, the general picture is consistent with that presented by Kwon and Mak (1 988) in a study of nonlinear barotropic instability on a β-plane. For a wide range of wind speeds and friction parameters, a steady state dominated by one wavenumber results. Longer wavelengths are dominant for stronger jets and smaller friction parameters. The equilibrated state for some specific sets of parameters is a stable limit cycle with wave amplitudes fluctuating regularly in time. Studies of a jet for which the vorticity gradient changes sign in high latitudes result in incoherently fluctuating states for all cases.

The periods of equilibrated waves in most cases remain similar to those of the linearly" unstable modes, and are dispersive or nondispersive depending on the characteristics of the linear modes. In cases where the growth rate of the linearly most unstable mode is considerably faster than that of the wave that is eventually dominant, the period of the dominant equilibrated wave may be much longer than that of the linearly unstable mode with that wavenumber.

Relevance of these results to the stratosphere is discussed. The results reinforce the correspondence between characteristics of barotropically unstable modes and observed waves that was seen in linear studies. Westward-moving modes arising from an easterly midlatitude jet appear to have amplitudes similar to those of observed features. Eastward-moving midlatitude modes have smaller amplitudes than the largest observed features; however, it is the smaller observed features that previous studies suggested might arise from barotropic instability. The direction and latitudinal structure of momentum fluxes are very similar to observations. Fast eastward-moving polar modes show "blobs" that move around the pole and retain their identity for a number of revolutions, in a manner similar to observations of the stratospheric 4-day wave, Momentum fluxes calculated from these modes are similar to those observed in the stratosphere.

A westerly jet whose vorticity gradient changes sign both in the polar region and in midlatitudes is also studied. It is shown that when a steady wave state emerges, midlatitude modes are dominant, and polar modes appear to be partially suppressed. For incoherently fluctuating states, midlatitude and polar modes co-exist, with little apparent effect on each other.

Reference

Kwon, H. J., and M. Mak, 1988: **On** the equilibration in nonlinear' barotropic instability. *J. Atmos. Sci., 45,* 294-308.